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The Effect of Grip Span on Hand-gripping Control Strength

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Abstract. The economic developments and industrial progressions, the automatic operations were getting more wide-spread. However, currently in various operation occasions, the workers are still required to face how to operate all kinds of hand tooling and equipments. In the industrial cases, there were many opportunities to use hand grip strength to operate machines. Hand grip strength has received increasing attention from industrial engineers and ergonomic researchers. The relation between hand grip strength and tool's grip span was important issues in ergonomics. Occasionally, it was little research to conduct. This study aims at exploring the relationship of tool's grip span and hand grip strength. Seventy two subjects rose from volunteers' participators, including 29 males and 43 females. Dependent variables were maximum volitional contraction and hand gripping control (HGC-$_{70\%}$, target value 70% MVC). Three different diameters of grip span were significance differences in maximum volitional contraction and hand gripping control. The study finds that the best diameter of tool's grip span was 47.6 mm. The finding will be served as a reference for task design, instrument design as well as for disease protected for industrial staffs.

Introduction

There are two kinds of important hand-grip strength in our daily tool operation, maximum grip force and hand-gripping control strength. Hand-grip strength is crucial to the human body for controlling objects. Many researchers have focused their efforts on understanding the factors related to the design of industrial safety equipment and tools that are related to hand-grip strength, maximum volitional contraction (MVC) [1-9]. Those studies result that hand-grip strength is a critical source of power for work-related operations. Whereas, the daily tool operation by hand is not only related to maximum grip force, but is also relevant to hand-gripping control strength, a control ability of force exert precisely by hand palm [10, 11]. For example, what is the exact amount of force required to cut off an electrical wire? How much force is required to drill a screw tightly? That strength is known as hand-gripping control strength (HGC). Hoeger and Hoeger [11] showed that by taking advantage of the percentage of MVC, to work the figures as test standards (e.g. 70% of maximum volitional contraction force is usually taken as measurement standard, expressed as MVC-$_{70\%}$). HGC is commonly used for daily tasks, work performances and tool operations [10, 12, 13]. Hand-grip strength has been proposed as a possible predictor of mortality and the expectancy of being able to live independently. Hand-grip strength measurement is a simple and economic test that gives practical information about muscle, nerve, bone, or joint disorders. An understanding the amount of the HGC for all types of workers can be used as a reference for designing new hand tools. Numerous studies showed that hand-grip strength is influenced by several factors including age; gender; posture; and grip span [7, 14, 15]. Occasionally, grip span is the most important factor that influences the grip strength and offers the knowledge for tool designing. The variation of grip strength with grip span has been reported by many researchers [16-21]. The maximum grip force that can be exerted is strongly dependent on the population (industrial workers, students, or ethnic groups) tested and the grip span itself (preferred versus a fixed span) found most of the studies describe an optimal handle separation, giving the maximal force [22]. A precise location of optimum grip span is as a function of one's modified thumb crotch length for an isometric power grip exertion, maximum voluntary isometric grip force, muscular activity, and subjective rating [23].

Conclusion, the highest maximal force from each of the fingers was obtained at a handle separation of 50-60 mm for females and 55-65 mm for males in European people. Howerve, the optimal handle separation for hand-gripping control strength has not yet been studied in Taiwan population.

Hand-gripping control strength, performed with fingers grip control, is one of interest issue to hand-held control tool work because of its importance in tool design. To our knowledge, the relationship between hand-gripping control strength and grip span has not yet been studied. In additionally, because of population differences, optimal handle separation of maximal force exertion in Taiwan population might be different in the western countries. So that, the objectives of this study were to evaluate the hand-gripping control strength of Taiwanese with varying grip spans and with a "free" posture, and to find the optimum grip span. Understanding the optimal handle separation of tool's grip span is benefited for equipment design.

Materials and Methods

Subjects

Due to MVC depends on age, and in generally, young people are reached the maximum value in grip strength in Taiwan (male 20-year, female 17-year) [24-25], therefore the study adopted the young participant as subjects to evaluate their MVC and HGC. Seventy two healthy subjects (29 males, 43 females) random selecting from Taiwan Shoufu University grade 1 to grade 4 students between the ages of 18 and 30 participated in the study after receiving information about the aim and clinical implications of the investigation. Mean age was 20.6 (±1.88) years. All the subjects included in the present study did not have any muscle- or joint-related injuries and free of any lesion or impairment in the upper limbs. As previously reported [26], the subjects were encouraged to do their best when performing the tests and were advised not to perform strenuous physical activity in the 24 hours before the preceding tests.

Methods

Measurement of handgrip strength. Maximum volitional contraction strength was measured using the hand-grip dynamometer in minute style (Japanese style, Tkk 5001) as shown in Fig. 1. When performing the dynamometry, subjects maintained the standard bipedal position during the entire test with the arm and upper arm at a 90-degree and did not touch any part of the body with the dynamometer except the hand being measured [27]. The test position is shown as in Fig. 2. Each subject performed the test 3 times using different grip spans and held onto the hand-grip dynamometer tightly for approximately 3 s, relaxed, and then repeated the operation 3 times. Participants took a 10-s break between each operation. After consecutively performing the experiment for 30 min, participants rested for at least 5 min. For each measure the right hand and left hand to be tested. The grip spans used were 47.6, 60.3, 73.0 mm, which corresponded to 5 different positions on the TKK dynamometer.

Figure 1. Hand grip dynamometer in minute style.

Figure 2. Posture of handgrip strength measurement.

Measurement of hand-gripping control strength. Hand-gripping control strength was measured using the same hand-grip dynamometer on all occasions (Japanese style, Tkk 5001). Measurement processes for hand-gripping control strength (HGC) were performed according to the methods and instruments used by Murase et al. [28]. Tests for HGC used a specified figure as the standard, and participants were asked to attain this standard accurately as possible, and the deviation between the standard and the participants' grip level was calculated. The lower value of the deviation indicated the better hand-gripping control strength. Thehigher value of the deviation indicated the worst hand-gripping control strength. To determine the accuracy of HGC, The Equation (1) was used, as shown in below [7]:

$$HGC_{-70\%} = |F_0 - F_i|/MVC \quad (1)$$

$HGC_{-70\%}$: hand-gripping control strength with an $MVC_{-70\%}$ indicated value

F_0 (kg): an indicated hand grip value

F_i (kg): the estimated value of actual grip of the person being exerted

$|F_0 - F_i|$ (kg): the absolute value after deduction between F_0 and F_i

The F_0 adopted in this study was 70% of the value obtained from the average when a participant's maximum volitional contraction was tested 3 times as the standard of $HGC_{-70\%}$ [the data were 70% of MVC ($MVC_{-70\%}$)]. F_i was performed with 3 times. The benefits and disadvantages of $HGC_{-70\%}$ were determined according to the deviations between the hand-grip value performed by the participants and the targeted loading value of $MVC_{-70\%}$. A smaller absolute value of the deviation indicated the greater accuracy of the hand-gripping control strength, whereas a larger absolute value of the deviation indicated a lower accuracy of the hand-gripping control strength [28]. After completing the tests, all data were analyzed by statistical analysis software SPSS 17.0.

Results

Hand-gripping control strength Test

All subjects completed the tests satisfactorily. The result of the hand-gripping control strength ($HGC_{-70\%}$) tests for right hand and left hand are shown as in Table1, and Table 2, respectively. As shown in Table 1, 3 times test's reliability was ≥ 0.973, it was an excellent reliability. The best value at last column as shown in Table 1 was the best hand-gripping control strength exertion on the 3 times measurements. It calculated by Equation (1). The mean ± SD of $HGC_{-70\%}$s were 2.748 (5.346), 3.271 (5.992), 4.209 (6.664) for grip span at 47.3, 60.3, and 73.0 mm respectively. The relation between grip span and hand-gripping control strength was existed. The one-way ANOVA results for grip span showed that the 3 grip spans demonstrated significant differences in $HGC_{-70\%}$ ($F = 3.914$, $p = .022$). A post-hoc (LSD) test showed that the 47.6 mm and 60.3mm grip span were not different from each other but different from the 73.0 mm grip span for dependent variable. Grip span 47.3mm obtained the lowest value of hand-gripping control strength at each grip span ($p < .05$). The exerted value of hand-gripping control strength at 47.6 mm grip span was 2.748*E-02, Which means the grip control error, was 2.748 % respect to individual maximum volitional contraction. Consequently, the optimal grip span at right hand's hand-gripping control strength is 47.6 mm for Taiwanese young people.

Table1. Hand-gripping control strength (HGC-$_{70\%}$) determined in all subject s(n = 72) for right hand

		Right hand					
		1(*E-02)	2(*E-02)	3(*E-02)	Reliability (α)	Average(1-3) (*E-02)	Best Value(*E-02)
Grip span	47.6 mm	5.424(8.045)	6.388(8.255)	5.816(6.441)	0.975	5.876(6.389)	2.748(5.346)
	60.3mm	6.896(11.04)	6.579(9.055)	6.074(7.354)	0.975	6.516(8.036)	3.271(5.992)
	73.0 mm	7.969(9.950)	6.816(7.378)	6.942(8.627)	0.973	7.242(7.976)	4.209(6.664)

As shown in Table 2, 3 times test's reliability was ≥ 0.980, it means 3 time tests having high correlated and was an excellent reliability. The best value at last column of Table 2 indicated the best hand-gripping control strength exertion on the each measurement. It calculated by Equation (1). The mean ± SD HGC-$_{70\%}$s were 3.119 (4.782), 2.427 (2.715), 3.023 (3.243) for grip span at 47.3, 60.3, and 73.0 mm respectively. By contrast as right hand, the one-way ANOVA results for grip span showed that the 3 grip spans demonstrated non-significant differences in HGC-$_{70\%}$ ($F = 0.932$, $p = .936$). The exerted value of hand-gripping control strength at 60.3 mm grip span was 2.427*E-02, which means the grip control error, was 2.427 % respect to individual maximum volitional contraction. Grip span at 60.3 mm exerted the lowest value of hand-gripping control strength on the 3 grip spans. Consequently, the optimal grip span of left hand's hand-gripping control strength is 60.3 mm in Taiwanese young people.

Table 2. Hand-gripping control strength (HGC-$_{70\%}$) determined in all subjects (n = 72) for left hand

		Left hand					
		1(*E-02)	2(*E-02)	3(*E-02)	Reliability (α)	Average(1-3) (*E-02)	Best Value(*E-02)
Grip span	47.6 mm	6.310(7.139)	5.410(7.110)	5.532(5.919)	0.980	5.751(5.964)	3.119(4.782)
	60.3mm	6.037(6.525)	5.276(5.216)	4.813(4.472)	0.982	5.375(4.027)	2.427(2.715)
	73.0 mm	6.444(6.110)	4.985(4.440)	5.443(4.477)	0.990	5.624(3.845)	3.023(3.243)

Handgrip strength Test

The result of the handgrip strength test, MVC for right hand and left hand are shown as in Table3, and Table 4, respectively. As shown in Table 3, 3 times test's reliability was ≥ 0.984, it was an excellent reliability. The best value at last column of Table 3 indicated the largest handgrip strength exertion on the each measurement. The mean ± SD of MVCs were 31.31(10.6), 30.13(10.5), 27.02(9.6) for grip span at 47.3, 60.3, and 73.0 mm respectively. The relation between grip span and maximum volitional contraction was existed. The one-way ANOVA results for grip span showed that the 3 grip spans demonstrated significant differences in MVC ($F = 50.99$, $p = .000$). A post-hoc (LSD) test showed that the 47.6 mm and 60.3mm, 47.6 mm and 73.0, 60.3mm and 73.0 mm grip span were significant differences from each other for dependent variable (47.6 mm > 60.3mm > 70.3mm). The value of grip span at 47.6 mm produced the highest value of MVC on the 3 grip spans. Consequently, the optimal grip span at right hand's handgrip strength is 47.6 mm in Taiwanese young people. The relation trend between grip span and maximum volitional contraction was as the same in the hand-gripping control strength (HGC-$_{70\%}$).

Table 3. Handgrip strength determined in all subjects (n = 72) for right hand

		Right hand (kg)					
		1	2	3	Reliability (α)	Average(1-3)	Best Value
Grip span	47.6 mm	29.72(10.5)	29.32(10.8)	29.58(10.5)	0.984	29.58(10.5)	31.31(10.6)
	60.3mm	29.08(10.7)	28.72(10.0)	28.67(10.1)	0.989	28.67(10.1)	30.13(10.5)
	73.0 mm	26.19(9.6)	25.56(9.7)	25.65(9.3)	0.990	25.65(9.3)	27.02(9.6)

The result of the handgrip strength test, MVC for left hand are shown as in Table 4. As shown in Table 4, 3 times test's reliability was ≥ 0.985, it was an excellent reliability. The best value at last column of Table 3 indicated the largest handgrip strength exertion on the each measurement. The mean ± SD of MVCs were 31.87 (10.4), 29.70 (10.3), 26.28 (9.6) for grip span at 47.3, 60.3, and 73.0 mm respectively. The relation between grip span and maximum volitional contraction was existed. The one-way ANOVA result for grip span showed that the 3 grip spans demonstrated significant differences in MVC (F = 120.60, p = .000). A post-hoc (LSD) test showed that the 47.6 mm and 60.3mm, 47.6 mm and 73.0, 60.3mm and 73.0 mm grip span were different from each other for dependent variable (47.3mm＞60.3mm ＞70.3mm). The value of grip span at 47.6 mm produced the highest value of MVC on the 3 grip spans. Consequently, the optimal grip span for right hand's handgrip strength is 47.6 mm in Taiwanese young people. The relation significant differences between grip span and maximum volitional contraction was not the same in the hand-gripping control strength (HGC-$_{70\%}$).

Table 4. Handgrip strength determined in all subjects (n = 72) for left hand

		Left hand (kg)					
		1	2	3	Reliability (α)	Average(1-3)	Best Value
Grip span	47.6 mm	30.77(10.6)	30.34(10.0)	29.97(10.1)	0.985	30.36(10.1)	31.87(10.4)
	60.3mm	29.06(10.3)	28.56(10.1)	28.45(9.9)	0.995	28.69(10.1)	29.70(10.3)
	73.0 mm	25.68(9.6)	24.80(9.6)	24.72(9.3)	0.993	25.07(9.4)	26.28(9.6)

Discussion

The result presented here showed that when measuring hand-gripping control strength (HGC-$_{70\%}$) there was an optimal grip span at right hand which let the standard dynamometer could exert the best hand-gripping control strength. The relation between grip span and hand-gripping control strength was existed. The optimal grip span was grip span set at 47.6 mm, which occurs for all both male and female. The result was the same as in maximum volitional contraction. These results are in accordance and complement with these data [29]. The result presented here showed that the optimal grip span 47.6 mm was less than that in Mahmut's data [23], 50-60 mm for females and 55-65 mm for males in European people. The difference might be cuased by samll hand size in Taiwanese young people population[2] and by subjects were combined the male and female together [19]. Jonathan et al. [19] reported that optimal grip span correlated in women but not in men. In present study, the aim was in order to compare the hand-gripping control strength and maximum volitional contraction in different grip span, so that the study combined male and female together.

By contrast in right hand, optimal grip span of left hand is a fixed value (60.3mm) and was not significant differences in each grip span for HGC-$_{70\%}$s. However, the one-way ANOVA result for grip span showed that the 3 grip spans demonstrated non-significant differences in each grip span for HGC-$_{70\%}$s. In addition, the optimal grip span was 47.6 mm which occurs at maximum volitional contraction, the same as in hand-gripping control strength. Therefore, the optimal grip span is a fixed value (60.3 mm) might be entered in acceptable range.

In conclusion, the result presented here showed that hand-gripping control strength (in the 70 % of maximum volitional contraction as indicated hand grip value) exerted the less error in 3 different grip spans, the best grip span was 47.6 mm in Taiwanese young people. This grip span is the same as in the maximum volitional contraction exertion in JAMAR hand dynamometer. The finding of this study could offer the data for tool handle designing, when ergonomic and industrial staff was required to precede design work. Finally, suggests from this study were that subjects came from undergraduate students an urban setting, and specifically the female did not perform hard manual activities, so that the grip strength might be small. Next research might enlarge the population in order to rise the reliability and validity.

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